

Long Term Surface Salinity Measurements

Final Report

Raymond W. Schmitt
MS 21, Dept. Physical Oceanography
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (508) 289-2426 FAX: (508) 457-2181 E-mail: rschmitt@whoi.edu

Neil L. Brown
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (508) 289-3381 FAX: (508) 457-2165 E-mail: nbrown@whoi.edu

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LONG-TERM GOALS

Our long-term goal is to establish a reliable system for monitoring surface salinity around the global ocean. Salinity is a strong indicator of the freshwater cycle and has a great influence on upper ocean stratification. Global salinity measurements have potential to improve climate forecasts if an observation system can be developed.

OBJECTIVES

This project is developing a new internal field conductivity cell that can be protected from biological fouling for two years. Combined with a temperature sensor, this foul-proof cell can be deployed widely on surface drifters. A reliable *in-situ* network of surface salinity sensors will be an important adjunct to the salinity sensing satellite AQUARIUS to be deployed by NASA in 2009.

APPROACH

A new internal-field conductivity cell has been developed by N Brown, along with new electronics. This sensor system has been combined with a temperature sensor to make a conductivity – temperature (C/T) sensor suitable for deployment on drifters. The basic sensor concepts have been proven on a high resolution CTD. A simpler (lower cost) circuit has been built for this application. A protection mechanism for the conductivity cell that includes antifouling protection has also been designed and built. Mr. A. Walsh of our commercial partner E-Paint has designed and delivered time-release formulations of antifoulants for our application. Mr. G. Williams of partner Clearwater Instrumentation advised on power and communication issues and supplied surface drifters for testing.

WORK COMPLETED

The conductivity cell has been constructed in ceramic and has been incorporated into a rotating shutter mechanism that isolates the cell from biological fouling (Figure 1). The electronic circuitry has been constructed and extensively tested for stability and noise characteristics. Antifoulants “pads” for this sensor have been delivered by partner E-Paint, after extensive testing for optimal antifouling performance. There are two main types of conductivity cell for making salinity measurements, inductive and electrode. Both are available in enclosed field configurations. However, because of thermal mass and flushing issues, we chose to use a new 4-electrode design due to N. Brown. This cell has low thermal mass and is readily flushed. It is constructed of ceramic, though a plastic version is under development.

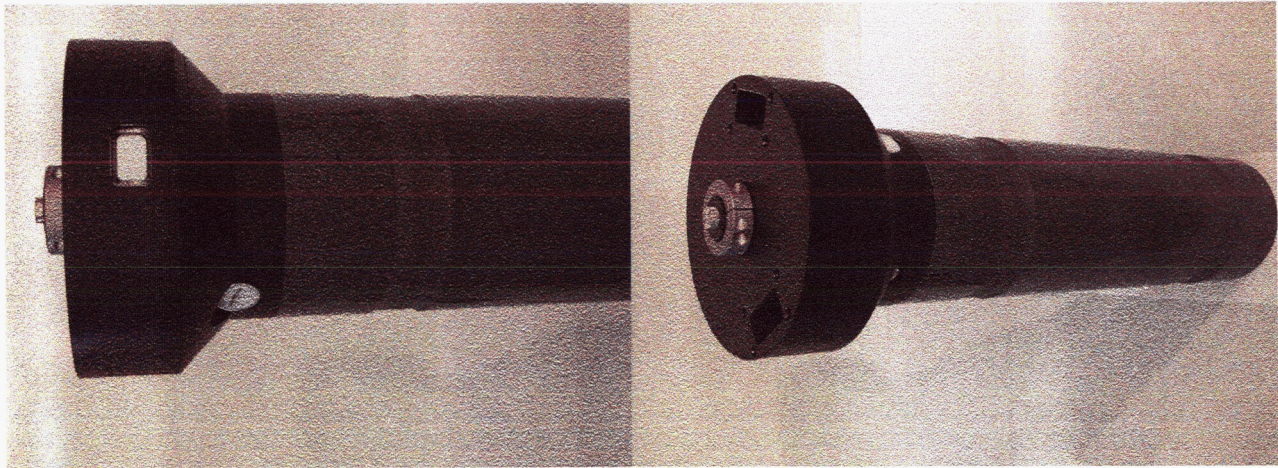


Figure 1.a, 1.b. The protected cell conductivity-temperature sensor. The left panel shows the open passage to the conductivity cell; the right panel shows a closed shutter system with the ports for the antifouling pads in view.

Unlike the NBIS MarkIII external field cell, the enclosed nature of the field makes any changes in near-cell geometry irrelevant; only changes in the internal geometry can affect the cell constant. Thus, it is suitable for protection with an enclosure mechanism. Our enclosure scheme uses a rotating shutter with a measurements channel that is off-axis. A 180 degree rotation of the shutter changes from closed to open position. When closed the measurement volume is exposed to special slow release antifoulants cast in a hydrolysable polymer. The antifoulant was formulated by project partner E-Paint, Inc. In addition a light activated antifoulant coating from E-Paint was used to paint the exterior portions of the entire unit. E-Paint formulations avoid the use of banned substances such as tri-butyl tin and are EPA approved for use in the marine environment.

The rotating shutter uses a conical bearing with a heli-coil drive mechanism that lifts it slightly in order to overcome excessive binding friction, in case of long duration parking. It is powered with a high efficiency geared DC motor. In normal use we plan for hourly sampling with a one-two minute sampling period with the shutter in the open position. Measurements of the flushing of the cell show that this is sufficient in even a low energy environment.

The sensor electronics and motor controls are contained on one 3.25" x 6.5" card (Fig 2.). A microprocessor controlled, transformer based referencing circuit provides self calibration of the signal processing electronics. Both temperature and conductivity sensors are driven by 1000 Hz square wave AC signals. The sensor output and reference signals are multiplexed into a single channel where they are amplified and synchronously detected then digitized by the 24 bit, sigma-delta type A/D converter. Variations of circuit parameters with temperature and time are readily removed through digital processing by the microcontroller since sensor and reference channels share a common signal path. The electronics are AC isolated from seawater by transformer/capacitor coupling of the conductivity cell. The drive level of the thermistor circuit is chosen to minimize the effects of self heating.

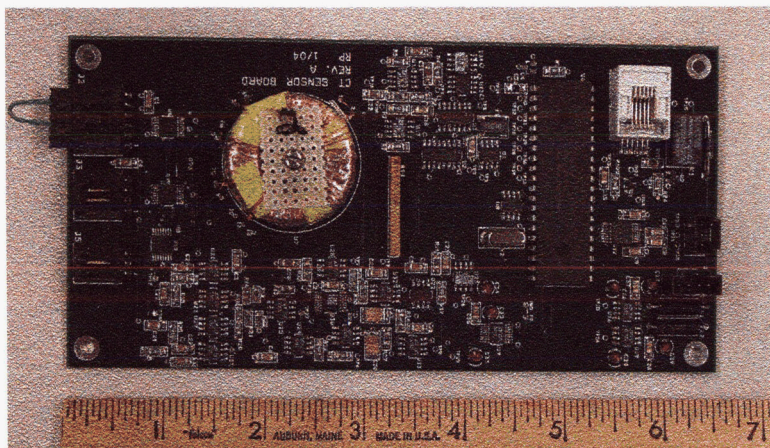


Fig 2. Electronics card for motor control as well as sensor driving, synchronous demodulation and A/D conversion. It measures 3.25" x 6.5" and has one transformer.

The PIC16F877 microcontroller is responsible for initiating A/D conversions and controlling the signal multiplexer. The start of each conversion is also synchronized with the 1 kHz clock to minimize the effect of ripple on the detected data signals. Digital data is communicated off board through an RS232 serial port. The board can be configured for sample rate, serial baud rate and for different data output and timing modes. The board consumes 200 mW at 15 V when sampling but enters a low power sleep mode on command.

PERFORMANCE

Tests of the instrument have been made at the dock of the Woods Hole Oceanographic Institution during the summer-spring fouling season. The sensor was deployed below surface (at low tide) by strapping to a strut (Fig. 3). Power and data communication were maintained by a cable to a nearby van which housed a power supply and logging computer.

Part of the record from a deployment is shown in Fig. 4. The regular diurnal heating signal is clearly seen in temperature and conductivity, but only a slow change in salinity is seen. Pre- and post deployment calibrations confirmed the stability of the sensor suite. While the slow release antifoulants have worked well to prevent biological colonization within the cell, we can anticipate that inert detritus may coat cell surfaces in particularly dirty environments. In order to address this problem we are devising a modified design that incorporates physical cleaning of the cell with the shutter rotation.

Fig 3. The C/T Sensor at the WHOI dock after three months deployment. Algae has colonized the support strut and clamps but the instrument itself has remained largely clear of fouling.

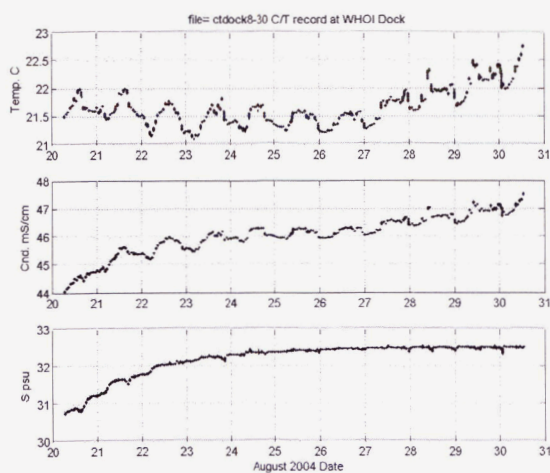
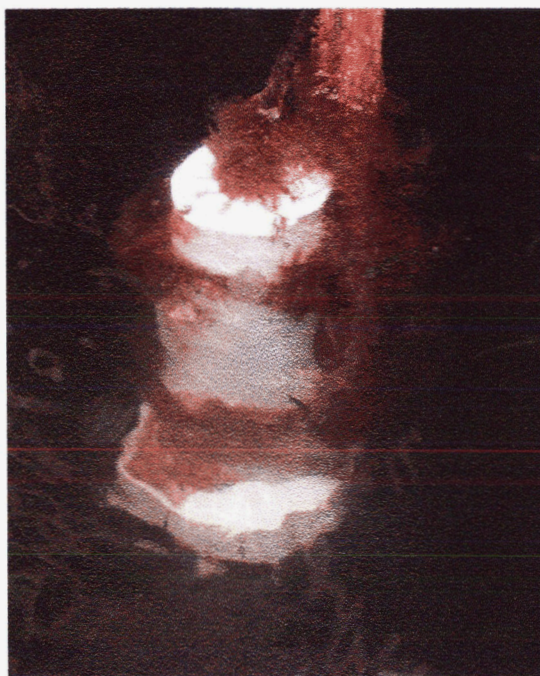


Fig.4. Temperature (top panel), Conductivity (middle) and Salinity (bottom) from an 11-day portion of the record.

IMPACT AND APPLICATIONS

Economic Development

The development and widespread deployment of a stable salinity sensor for the upper ocean will lead to an improved understanding of the role of the oceans in the climate system. Theory tells us that this implies improved predictability of decadal climate change, which would have tremendous societal benefits.

Quality of Life

Sea surface salinity is a direct indicator of changes in the global water cycle, which is the major climate change issue of concern to society. It is also a key factor determining the potential for abrupt climate change due to collapse of the thermohaline circulation. A better understanding of climate and improved climate forecasts would impact farming and fisheries, and greatly improve planning for water use and energy demand.

TRANSITIONS

Economic Development

It is expected that the new sensor will be transitioned to a commercial product by licensing to an appropriate manufacturer.

PUBLICATION

R. W. Schmitt, R. Petitt, F. Thwaites and N. Brown, 2005. A Fouling Protected Conductivity Sensor For Long-Term Salinity Measurements In The Upper Ocean. Proceedings, MTS/IEEE Oceans 2005, September, 2005.

ACKNOWLEDGEMENT

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